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ANNUAL REPORT

ON THE

GOVERNMENT EXPERIMENTAL FARM, CAWNPORE,

FOR THE YEAR ENDING 1878-79.

Note by Director, Dept. Agriculture and Commerce.

CAWNPORE EXPERIMENTAL FARM.

Official Management of the Farm.

The farm work is now divided under two heads :—

I.—Agricultural experiments, which consist mainly in the measurement of results of various methods of cultivation.

II.—Mechanical experiments, which relate to the development of agricultural machinery.

2. Progress under the first of these classes has been much impaired by the neglect of the managing superintendent which led, under circumstances already reported to Government, to his enforced resignation. Progress under the second class may be accepted as considerable.

3. Since the removal of the late superintendent in October last, Mr. Fuller has been placed in responsible charge of operations, and has been provided with accommodation in the house belonging to the department near the farm lands, in which, pending other arrangements, he will continue to reside during the greater part of the year.

4. Previous reports have noticed the initial attempts which had been made at the farm for the development of agricultural workshops. Mr. Fuller since joining the department had personally superintended work in this direction, and by last May had made no little progress in the modification of English ploughs for native requirements.

5. I had also during 1878 and 1879 prepared on the farm premises, for the scientific trial of various kinds of waterlifts, a series of wells and measuring tanks, the construction of which occupied a considerable time, but which during last rains were brought to completion. They were so constructed that any kind of waterlift could be tested in them, and meanwhile I had procured from Roorkee or had had constructed on the farm such models of waterlifts as I could obtain.

6. While these operations were in progress, I lost no opportunity of representing to Government the importance of attaching to the department the services of a skilled engineer, on the ground that the development of machinery suited to the country must be kept under the control of skilled supervision, for very obvious reasons, some of which will be presently recorded.

7. The result was that Mr. Jones of the Irrigation Department, in charge of workshops at the Narora head works of the Lower Ganges Canal, was in May, 1879, temporarily transferred to the department, but in consequence of his services being required for railway purposes, was very shortly afterwards transferred to the Rajputana State Railway.

8. I then made an urgent request for the services of another engineer, and as it so happened that the committee appointed in 1878 for investigating questions connected with the deterioration of land under the influence of *Reh* (saline efflorescence) had at about the same time strongly

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recommended Government to place the scientific investigation of *Reh* phenomena under a special officer, it was determined by Government to depute permanently to this department an engineer from the Public Works Department. Mr. Wilson of the Irrigation Department was specially selected by Colonel Brownlow, the Chief Engineer, Public Works Department, for the appointment, and this officer joined at Cawnpore in the month of August. His report on the comparative results of the different classes of waterlifts tried on the farm, to which I will refer again, is appended. Mr. Wilson has since been transferred to another district, to take charge of operations connected with *Reh*, but will continue to give his assistance to Mr. Fuller at Cawnpore when required to do so.

9. At the beginning of the year I took on the farm a European apprentice (Mr. Crawley) who had had some years' experience in farming and flax-growing in Ireland. He is now in immediate superintendence of operations under Mr. Fuller's orders, and occupies the late Superintendent's house on the grounds. So far he has proved trustworthy and careful.

10. I had sometime ago determined that experimental work should as far as possible be transferred from the farm area to a neighbouring Court of Wards' estate known as the "Rawatpur" estate, which is likely to remain under Government management for several years. An opportunity was given to me to do so by the orders I received from Government to take any advantage of Court of Wards' estates for agricultural experiments, so far as they did not involve unremunerative outlay to the treasury of the estates.

11. The following quotation from one of my letters will explain my reasons for wishing to carry out agricultural operations on the Court of Wards' villages rather than on the farm :—

"The farms which Government maintains cannot be termed model farms, "partly because for one thing in which we can beat the native, he can beat us in a "hundred, and partly because if the farm was cultivated on Government account, "peculation and dishonest labor would destroy the value of every result. As it is, "native dishonesty goes far to impair the value of experimental cultivation, but it "would absolutely ruin any attempt at model farming. Every man employed to cut "the crops, to thresh, winnow or store the grain, or to sow the seed, takes something "of what passes through his hands, and thus prevents accuracy of measurement, while "by shirking their work, the cultivating laborers prevent accuracy of the record of "cost. The only hope of ensuring true experiments is to adopt a system under which "cultivators will carry them out on their lands for their own benefit."

12. The situation of the Rawatpur estate offered a convenient opportunity for establishing a system of agricultural experiment by the best agency, that of cultivators themselves, under our own directions.

Farm operations.

Before noticing the operations described by Mr. Fuller and Mr. Wilson, I will repeat the remarks which I placed nearly a year ago before Government in explanation of the principles which have been adopted in developing experimental operations for the adaptation of foreign machinery to native requirements.

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"In the first place, we have to deal with a climate and with conditions of soil "completely at variance with those of England. The most skilled English agricul- "turist ought, therefore, to have the greatest diffidence in proposing any change, "founded on any English experience, in a system of cultivation which has been "evolved by centuries of 'natural selection.'

"Every English machine or implement may, in the first place, be condemned as "*primâ face* unsuitable for India, notwithstanding even that the principle on which "it is contructed may be equally sound for Indian as for English conditions. The "onus of proof will always lie on the side of establishing that an English machine is "useful to this country, and not on that of proving that it is not useful. Hence "our farms must (*quoad* machinery) be experimental, not model.

"The chief objections to English machinery (the word is intended to include "'implements') are, first the price, utterly and completely out of the reach of the "mass of Indian cultivators; the second is the cheapness of labor with which machi- "nery has to compete, and the third is their unsuitability to Indian conditions.

"We have therefore to begin firstly, by reducing the cost of construction of "machines; secondly, by limiting our machines to those which will increase the "effect of available labor rather than economise or provide a substitute for labor; "thirdly, by modifying the machines until they are suitable for Indian conditions. "It follows that, until these objects are effected, we cannot, so far as machines are "concerned, come forward to advise natives to adopt any class of machines, or to "attempt to instruct them in their use.

"The second point noticed requires illustration by a practical example. A well "bucket (A) has been invented which is drawn by *one* bullock and *one* man, the ordi- "nary bucket in use (B) is drawn by *two* bullocks and *two* men; B raises less than "double the water raised by A. But A, though it economizes labor, does not "increase the effect of existing labor. B gets more out of existing labor than A; "the number of wells remaining the same. For this reason cultivators prefer B "to A.

"If, then, the position assumed is accepted, that we must ascertain how machi- "nery can be adapted to meet native conditions before attempting to introduce them "or instruct others in their use, then the first step is to choose the class of machines "to be adopted, the second to adopt them, the third to introduce them."

13. During the past year, or for a still longer period, we have adopted for experimental development three classes of machines, *viz.*, (1) Foreign ploughs, which I shall presently explain are implements new to India; (2) waterlifts, in which improvement will (if practicable) be of great service to an irrigating country, (3) grain-cleaners or sifters.

14. The next step has been to attempt their modification or adaptation to native requirements. An account is given in the appended reports of progress made in this direction.

15. The third step has been to commence their introduction.—That this has been effected with some measure of success in the case of ploughs, and with some prospect of success, in the case of waterlifts, is also shown in the reports. The adaptation of grain-cleaners is not complete, but it is intended that some should be ready for trial by next rabi harvest.

16. *A. Ploughs.*—Mr. Fuller, the assistant in this department, deserves much credit for the energy and perseverance which he has devoted to the development and construction of a cheap plough in which the

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mechanical principles of the English plough, altogether wanting in the native implement, is brought within reach of a native cultivator, as I have represented elsewhere. The Indian plough ought not to be called a plough at all. It is a grubber or toothed implement, which (as Mr. Fuller explains) stirs the soil without inverting it. It is an extremely good implement for the purpose it fulfils, and will probably never be superseded or ousted by any implement that we can introduce under the name of a plough. But it cannot be too often repeated, that the native implement, good as it is, is not, in English farm language, a plough at all, and that in introducing the implement which we are trying to establish, we are introducing a new implement into native agriculture and not trying to oust an old one. The same development has occurred in England. Diagrams from early English books prove the so-called Saxon plough to have been a very similar implement to that which has hitherto been known as the Indian plough, *i. e.*, a soil stirrer, and not a soil invertor. The new principle of "inverting the soil" by an implement drawn by cattle is of comparatively modern application. In fact, the plough of the Saxons has received a double development in recent agriculture, one of which is the soil-inverting plough, and the other the soil-stirrer, known under the various names of grubber, subsoiler, bull-tongue, &c.

17. At the same time, while the new principle of inverting the soil has been thus introduced, an attempt has been made to combine the further advantage of opening the soil to a greater depth than can be effected by the native implement. How far this can be successfully effected without a corresponding increase in the power of the cattle used for agricultural purposes is yet doubtful, but if increased depth of soil-stirring, as well as inversion of soil can be attained, a double advantage will have been gained. It is now a matter of trial, which the farm experiments will shortly bring to a certain conclusion, to what depth we can allow the soil inverting plough to be used without placing too great a burden on the cattle of minimum power, usually employed by cultivators. As Mr. Fuller points out, much difficulty has been occasioned by an imperfect knowledge of the method of using the new implement, which has led to its rejection in some cases on the plea that cattle have not been equal to its draught. But the experiments now being conducted will succeed in determining the exact draught which ordinary cattle can sustain when the plough is properly used, and meanwhile the principle has been adopted of discontinuing the distribution of ploughs until competent ploughmen can in the first instance be sent out to teach their use.

18. Mr. Jones and Mr. Wilson instituted some careful experiments (which are still being continued) to establish the average draught which an ordinary pair of bullocks can sustain, and this once determined, it will be a matter of mechanical adjustment to construct implements to which the strength of bullocks is adapted.

19. I wish to draw attention to those remarks made by Mr. Fuller, which indicate the great advantage which has been derived from American models. For cheapness and adaptation to Indian requirements,

they appear certainly in advance of English patterns, and I believe that it may be even found possible to obtain the ironwork from America almost as economically as it can be constructed here, with the great advantage that it will be far more durable.

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There is no doubt that a light American plough constructed in America is a more perfect instrument than we can (under any circumstances) make up in India, and that if we can import the metal portion from that country cheaply enough we shall be able to give to the cultivator a more useful instrument than any that we can make, and at the same time an implement which a native *mistri* can ordinarily put together and keep in repair without difficulty, since, if it occurs that any portion of the ironwork should break, a new piece of the same pattern would be supplied for a few annas.

20. I have not gone into the question whether soil inverting is or is not useful. I assume that it is. Of course, if the assumption is wrong, the advantage of a soil inverting implement disappears.

But so long as we have the experience of England, America and other civilized countries on our side, and so long as natives in India believe, as they do, in spade digging, so long are we entitled to presume that there will be an advantage in applying to this country the principle of the English plough, which may not be improperly termed a cattle drawn spade.

21. *B. Waterlifts.*—The object of the experiments in waterlifts is to ascertain whether any more effective machine than those now used can be placed in the hands of the agricultural population.

In order to solve this problem, it is necessary first to measure the effective work of existing appliances, next, to make experimental trials with new models, and to select any which are more effective than those existing. Thirdly, to adapt models thus selected, so as to bring them within the reach of native agriculturists.

For the purpose of measuring the work of different waterlifts the following arrangements have been made:—A masonry well about 50 feet deep has been constructed near a large tank, which latter is filled with water from the Ganges canal. The well is closed at the bottom with a brick floor, and a channel from the tank admits water to any depth required. This arrangement permits of the adjustment of any waterlift for depths not exceeding 50 feet. Near the well small masonry reservoirs are placed in which the water lifted in a given time can be accurately measured.

Of the general results obtained and recorded in Mr. Wilson's note the following is a brief abstract:—

22. Native appliances tested on the farm are three in number—

1. The swing-basket used by hand-power for depths not generally exceeding 5 feet.
2. The dhenkli, or earthen pot raised with lever by hand-power for depths of about 15 feet and under.

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3. The ordinary leather bucket worked by cattle on an inclined plane and generally used for depths exceeding 15 feet.

Persian wheels are little used in this province, and have not yet been tested on the farm, but statistics have been obtained from Bundelkhand, which are included in Mr. Wilson's note.

23. So far as observations have been recorded, baskets are most effective between 3 and 4 feet; and in terms of one Horse-Power the useful work done by 4 men is about 0 08—or 0·02 per man.

24. The work of one man at a dhenkli raising water from 13 to 15 feet is equal to about 0 03 of one Horse-Power. It must be however borne in mind that one man is in each case required on the field to regulate the distribution of water, and that with the dhenkli much less work is required from this man than in the case of the basketlift (by which much more water is raised in the same time). It is usual therefore for the two men at the dhenkli to take turns in raising water, whereas the fifth man at the basket does not assist. This circumstance makes the work done per man in the two cases nearly equal, and gives as a fair working unit 0 02 of a Horse-Power as the effective work of one man.

25. In the third case, that of the leather bucket, which may be said to be the ordinary waterlift of the province, the effective work of 2 bullocks increases considerably with the distance of water from the surface. The experiments, so far as they have gone, indicate the effective work per hour at 40 feet as about double that at 15 feet. In the former case it was 0·127 of a Horse-Power, in the latter 0 064.

26. The experiments are not considered final, and will be continued with different pairs of bullocks until a sufficient series has been recorded to justify more definite conclusions. Assuming however the results of the observations to afford a basis for calculation, the problem which has to be solved takes the following form :—

Can a waterlift, sufficiently cheap and easy of construction, be provided which up to 15 or 20 feet can be worked by manual labor, so that the effective work of each man employed will be greater than 0·02 of a Horse-Power, or which at a depth of from 15 to 40 feet can be worked by bullock labor, so that the work of a pair of bullocks is greater than 0·127 to 0·064 of a Horse-Power? The solution of this problem cannot, as I have indicated, be definitely undertaken until the data are more conclusively established, but the above statement will show clearly the method in which it has to be worked out.

27. Side by side with the above observations experiments have been tried to ascertain the effective value of new appliances, in order to provide data for the solution of the problem stated in the last paragraph.

These have been three in number; (1) a chain pump worked by hand labor ; (2) a chain pump worked by bullock labour ; (3) a double bucket worked by bullocks.

[The latter is only so far new that it has not been yet adopted by rative cultivators in the North-Western Provinces, though it has been

often the subject of experiment on experimental farms, private gardens and elsewhere.]

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28. The general results are these—

(1.) The chain pump worked by four men is proved to be very effective for lifts under 15 feet; the effective work of one man being about 0·034 of one Horse-Power.

(2.) That worked by bullock-power has only been tried at about 40 feet. It is much less effective than the ordinary leather bucket, the effective work of a pair of bullocks not exceeding 0·1 of a Horse-Power.

(3.) The term "double bucket" indicates that one bucket descends while another rises, both being worked by the same bullock or pair of bullocks. The effective work of one pair of bullocks, so far as experiments have been made, is about 0 18 of a Horse-Power. At depths up to 20 feet this exceeds the effective work of the ordinary bucket by about 50 per cent.

29. Another form of comparison is given by Mr. Wilson in tabulating the cost of the work performed by different appliances. The result is shown in the following table :—

Name of appliance.		Height of lift	Cost of raising 1 000 tons of water 1 foot high.
			Annas.
Manual labor,	Basket	3′ to 4′·5	14 1
	Dhenkli	13′	8 7
	Chain pump	10 5 to 15′	8 2
Cattle labor,	Ordinary water-bucket ...	20′ to 50′	14 0 to 9 6
	Double ditto ditto ...	20′	8 9
	Persian wheel	20	11 7

30. The results indicated in the foregoing remarks have justified an attempt being made to adapt the chain pump to native requirements. The working models first employed were :—

(1) A pump brought myself from Australia at a cost of Rs. 300.

(2.) A pump manufactured at Roorkee for about Rs. 100.

These prices are too high for ordinary cultivators, and can only be given in exceptional cases by rich zemindars. Experiments have been made by substituting, (*a*) sheet iron, (*b*) wood, (*c*) leather and bamboo, for the ordinary iron tubing. The result has been a reduction of cost to something like Rs. 20 to Rs. 30, though it is not yet determined which of the new models will be formed most permanently effective. There is every reason to believe that this waterlift (of which the principle has been adopted with success in Australia as well as on pumps used by cultivators on the Gházipur tobacco farm) will in one form or another be made readily adaptable to native requirements with great effect in all areas in which water is not more than 20 feet from the surface, and especially in those tracts (which are far from uncommon) in which bullock labor is deficient.

31. The above remarks will give a definite idea of the principles on which experimental work is being conducted. I cannot speak too highly

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of the energy and ability which Mr. Fuller and Mr. Wilson have devoted to it, and, as I have said, whatever improvement has been made in the plough is due to Mr. Fuller. I regret however the difficulty which has been experienced in finding a good farm superintendent. The choice lies between an incompetent man who knows something of the country and its agriculture, and a competent man who knows nothing of them. The criticism is true, that competent men in India have succeeded in providing for themselves elsewhere, and are not forthcoming, while the experiment of bringing out a farmer from England who may or may not succeed, is a dangerous one to adopt without much caution, and has been indeed viewed with disfavor by high authority, in one instance at least, in which it has been proposed. Moreover, as I have in previous reports explained, we were saddled at first starting with previously imported farmers of the wrong class, men more fitted to grow roses than wheat.

At the present time experimental work of one class, *viz.*, that affecting agricultural machinery is, in my opinion, making sufficiently good progress. Experimental work of the second class, *viz.*, that affecting methods of cultivation has been hitherto unsatisfactory, and although it will be placed on a much securer basis for the current year than the past year, and the assistant now on the farm under Mr. Fuller is a farmer of some experience at home, it remains a question, which will be brought under discussion elsewhere, whether or not scientific supervision should be obtained, and if so, in what way it should be provided.

E. C. BUCK,

11*th February*, 1880. *Director, Dept. Agri. and Commerce.*

REPORT

ON THE

CAWNPORE EXPERIMENTAL FARM,

FOR THE YEAR ENDING DECEMBER 31st, 1879.

Report by Mr. J. B Fuller

Official superintendence

AT the commencement of the year a new Superintendent was engaged, who, judging from the excellent recommendations he brought with him, should have proved himself more successful than his predecessors. But events have shown him to have systematically neglected orders from the very commencement of his tenure, and he is proved to have exercised no real supervision over the various operations in progress in the farm, and have trusted entirely to his native subordinates for the accurate recording of the results. An enquiry instituted in October last ended in his resignation from November 1st—the date from which I was put in immediate charge of the farm.

2. Under these circumstances I hesitate to put forward the various results which are represented to have been obtained. Unless they are guaranteed to be accurate, the publication of such results will be worse than useless, and the circumstances under which they were collected, and to some extent, the suspicious regularity and correspondence exhibited by the results themselves throw the very gravest suspicions on their accuracy. I therefore put aside all agricultural operations for the conduct and record of which the Superintendent was solely responsible, and confine the present report to the following three heads :—

(i.) Experiments in the reclamation of *reh*-infected land on the Ráwatpur Court of Ward's estate.

(ii.) The adaptation and construction of improved agricultural implements for Indian use, which were conducted under my immediate direction.

(iii.) Experiments on the comparative efficiency of various methods of lifting water, conducted for the most part on the farm premises by W. J. Wilson, Esq., Assistant Engineer, on special duty with this Department.

3. (i.)—*Experiments in the reclamation of reh-infected land on the Ráwatpur Court of Ward's estate.*

(i)—Experiments in the reclamation of *reh*-infected land on the Ráwatpur Court of Wards' estate.

A number of the villages which constitute the Ráwatpur estate are situated at only 2 or 3 miles distance from the farm premises, and the programme which was laid down for the guidance of the late Superintendent included the introduction into these villages of improved methods of cultivation under the orders of the Collector of the district. This remained a dead letter, and the only agricultural operations, worthy of the name, which were conducted on this estate, were some attempts to reclaim *reh*-infected land in the village of Sháhpur on the banks of the Ganges canal These experiments were not under the immediate charge of the Farm Superintendent, but of his Assistant, and I believe that they were conducted with fidelity and the results accurately recorded.

4. The ground operated on lies close under the canal bank, and is a fair specimen of *usar* land, covered with efflorescent salt in some places, and in others bearing scanty

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tufts of grass and, here and there, small *babúl* trees. The following is a summary of the experiments which were tried :—

No.	Area of plot.	Ploughing.	Manure.	Seed.	Watering.	Results.
1	½ acre,	Watered and ploughed with the English plough in May and again (8″ deep) in July.	*Ashes of the Madár (*Calatropis gigantea*)	Babul sown broadcast.	None ..	Seed germinated fairly well, the young trees now (December) 3″ to 6″ high, not looking healthy.
2	Do. ...	Ditto ...	Ditto ...	Juár, as a fodder crop	Ditto ..	Germinated unevenly, and in some places grew to a good height. The yield was only 13 maunds 14 seers of green fodder.
3	Do ...	Ditto ..	Ditto ...	*Madár (*Calatropis gigantea.*)	Ditto ..	Germinated well, but the young plants are now (December) withering.
4	Do. ...	Ditto ...	None ...	Babul, sown broad-cast.	Ditto ...	Germinated well and the plants are in rather better condition than on plot No. 1.
5	Do. ...	Ditto ..	Ditto ...	Madár ...	Ditto ..	Condition of crop similar to that of No 3
6	Do. ...	Ditto ...	Ditto ...	Rice ...	Was to have been kept flooded, but from failure of canal water this was impossible.	Only the plants situated on the high parts of the field grew to any height, the whole crop withered away when the ground was allowed to dry and only yielded 4½ seers of grain.

In addition to the above experiments the effect was tried on smaller plots of—

(*a*). Removing the upper crust of soil to the depth of three inches, and replacing it by earth dug from a pit in the corner of the field.

(*b*). Paring and burning the upper crust of soil, and re-spreading it.

(*c*). Surface draining by shallow trenches 5′ apart sloping into a pit at one corner of the field.

Although twice sown not a single seed germinated on plots (*a*) and (*b*); plot (*c*) was not to be sown till November, but appeared to give better results than any other of the plots experimented on, judging from the crop of grass it bore in the rains.

5. The processes experimented with, of the success of which some hope may be entertained, were therefore in the main three, (i.) deep cultivation two months before the rainfall, and again at the commencement of the rains ; (ii) manuring with madár ashes ; and (iii) surface drainage,—but it is too early as yet to form a definite conclusion as to their results, which in some cases (*i. e.*, babul cultivation) will not be complete under a full year. A portion of the ground has also been sown with rabi crops.

6. (ii.)—*The adaptation and construction of improved agricultural implements for Indian use.*

(ii.)—The adaptation and construction of improved agricultural implements for Indian use.

The implements which have engaged attention during the year are ploughs and waterlifts.

Ploughs.—The main difference between the European or American and Indian plough is that the one inverts the soil while the other merely stirs it. The popular idea which associates English ploughs with deep and the native implements with shallow cultivation must be accepted with much reserve. Enquiries have shown that, in the case of good cultivators at all events, the depth to which the ground is stirred in preparation for a *rabi* crop, is often equal to the average depth of English cultivation. This depth is generally attained by a laborious and costly system of ploughing and reploughing, and occasionally by the use of a more powerful implement than that ordinarily employed. Under the orders of the Director, Department of

**Madár* ashes were tried as a manure in consequence of the recommendation of several native zemindars, but its efficiency was not apparent in these experiments. *Madár* itself was sown with the object of determining whether the land could be made at small cost to produce a plant, the ashes of which would be serviceable when returned to the soil.

Agriculture and Commerce, a collection of the ploughs used in each district of these provinces has been commenced, and the differences thus brought out are very striking. In the majority of districts the plough which is used, though of varying shape, consists essentially of a tongue of wood fitted with a small iron tooth. But, to notice one or two of the most striking divergences from this type, the plough contributed to the collection by the Saháranpur, Muzaffarnagar, and Meerut districts are of nearly double the ordinary size and weight, are shod with a horse-shoe shaped piece of iron round the edge of the "tongue," and instead of a small iron tooth are fitted with a long pointed bar of iron which projects out behind the heel of the plough and can be forced forward as its point wears down. Another plough used in one portion of Bundelkhand (the *nágar*) weighs 3 mds., 14 seers, that is to say, considerably more than an ordinary English or American plough, and stirs up the earth to a depth of 9 inches or a foot. It is dragged by three pair of oxen and worked by nine men, yet so well appreciated are the advantages which result from its use, that cultivators club their oxen together for the purpose and plough each other's fields in turn.* It must be remembered that both the iron shod plough of the Meerut Division and the *nágar* of Bundelkhand, are only used by the most careful and painstaking classes of cultivators, but the fact of their being used disposes of many of the objections which are urged against the possibility of introducing European implements into the cultivation of this country, and proves not only that good cultivators recognize the advantages of deep cultivation, but that they are prepared to go to some trouble and expense to attain it.

7. The inversion of the soil which is effected by an English plough could however only be effected by the Indian cultivator through the expensive process of hand digging and the extent to which this is resorted to in the cultivation of some of the more valuable crops (*e. g.*, potatoes and sugar-cane) shows that the beneficial results (on some soils at any rate) are well known and appreciated. To dig an acre of ground by hand labor to a depth of six inches employs four men for five days, even in the comparatively soft soil of Rohilkhand; a plough on the European model worked by good bullocks can easily do this in two days. It is quite possible, or even probable, that inversion of the soil may cause at the outset some loss of produce. The earth which lies below the upper veneer of cultivated soil, has from non-exposure to the sun and air, never been properly disintegrated, and, if brought to the surface at the wrong season, will probably at first give less return than the upper layer. But cultivators readily admit, and experiments have proved, that the subsoil (if of the same character as the upper layer) will exhibit its natural fertility after a year's exposure, and the increased depth of the tilth will then largely add to the outturn. This is frequently to be observed in the case of land which has been disturbed to a greater depth than ordinary, and the sites of old embankments or watercourses, which have been levelled off into fields, are often marked for miles by the greater height and richness of the crops on them. If it is impossible to give land a fallow after inverting its soil, it should be ploughed at the commencement of the rains, and sown with an autumn crop, which is influenced far less than a spring crop by the rawness of the soil it is sown in. But the most favourable time for the use of an English plough would appear to be the end of the rains, followed by a fallow during the cold and hot weather months, or if possible, land should be watered and ploughed in April after the spring crops have been cut and carried. In no case is the English plough meant to supplant the native implement, which in its best forms is probably as effectual an instrument as could be devised for pulverizing the soil and for covering the seed.

8. The two chief objections to imported ploughs of either European or American manufacture were on the score of—

(i.) Their expense.

(ii.) Their draught, which was beyond the capacity of a pair of ordinarily good bullocks.

*The process is so expensive a one, that it is, as a rule, only followed in preparing land for sugar-cane.

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As regards the second objection, the case of the *nágar* of Bundelkhand may be urged as showing that it is by no means indispensable that the drawing power of a plough in this country should be limited to the usual one pair of bullocks. But such a system as that on which the *nágar* is worked presupposes powers of combination which are rarely possessed and would be only workable when the area to be deep ploughed each year was a very small one. The majority of cultivators cannot afford more than one pair of bullocks, and a plough which is to find favour with them must be of light enough *draught* to be drawn by one pair. It must also be of a light enough *weight* to be carried on the shoulder, cheap, and, if possible, should be easily repairable.

9. None of the English or American ploughs which had been imported fulfilled these requisites. Indeed, the ploughs which were imported previously to 1876-77 and which now for the most part lie useless in the farm store rooms, appear to have been ordered from England without any reference whatever to the *desiderata* of cheapness, lightness, and simplicity of construction. During the past two years several of the lightest description of English and American ploughs have been imported and thoroughly tried by me one against the other. But although the lightest of the American "Eagle" ploughs comes in its draught very nearly down to the required standard, the cost was always prohibitive, being in no case under Rs. 16 per plough. Experiments with a dynanometer gave good ground for the belief that for fairly good cattle, working eight hours a day, the average plough draught should not exceed 126lbs. This belief is not only based on measurements of the average draught overcome by different pairs of the Farm bullocks, when ploughing all day with English or American ploughs, but also on the fact that a very second rate pair of bullocks, getting no gram, worked regularly for 10 hours a day on a gin which turned a fan in the farm workshops, the average draught of which was 100lbs. The limit of price was fixed at Rs. 8, the utmost which could be expected from an average well-to-do cultivator. How far the ploughs experimented on fell short of these requirements may be judged of from the following table, which shows the weight, draught, and cost* (landed at the farm) of some typical ones.

		Weight.	*Average draught at 5 inches.*	*Cost.* Rs.
		ENGLISH.		
Ransome and Sims' B.F.O.,	...	64lbs.	196lbs.	24
Ditto Eagle,	...	38lbs.	178lbs.	17
Howard's D. Cotton plough,	...	77lbs.	220lbs.	34
		AMERICAN.		
Collin's cast steel ...	...	50lbs	180lbs.	25
Watts ...	...	42lbs.	150lbs.	12

The factors which contributed to these wide differences in draught were—

(*a.*)—The width of furrow slice, which in some cases was rather broader than in others.

(*b.*)—The weight of the plough itself, which has been proved by† experiment to constitute from 33 to 50 per cent. of the draught.

(*c.*)—Differences in the style of work done, *i.e.*, the furrow slice may be broken and thrown lightly aside as in the case of a short breasted plough of the "Eagle" pattern, or may be turned over in a regular "glazed" line as with a long breasted plough like the B. F. O.

10. It was determined to attempt to adopt from these patterns a plough which, while turning over the soil to the depth of 5 inches, should suffer as little increase of draught as possible from the three causes abovenamed,—breadth of furrow-slice, weight (which aids the ploughman by giving steadiness) and style being sacrificed as far as possible, in order to reduce the draught down to the limit which was fixed on. One of the questions to be decided at the outset was, whether it would not be better to

* The cost is calculated on the published catalogues of the manufacturers, taking Re. 1 as equal to two shillings, and adding 35 per cent. on account of freight.

†See a paper by Mr. J. E. Ransome, read at the R. A, College, Cirencester, and published in a series entitled "Practice, with Science."

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copy the native plough so far as to use a rigid beam for attaching the body of the plough to the yoke. This was found to be impracticable without adding considerably to the draught. From the nature of this attachment it was found impossible so to regulate the line of draught as to make it pass through the centre of the body of the plough (called the *zero point)* which is necessary for easy and steady ploughing. In English and American ploughs this is attained by the combination of a horizontal plough beam with slanting traces. If a rigid beam is used as the sole attachment, the line of draught terminates behind the zero point, and (unless considerable force is exerted, which adds largely to the draught) the heel of the plough has a tendency to be pulled up off the ground, and the plough travels on its point in much the same manner as an ordinary native plough. With the rejection of a rigid beam as the attachment, arose the question as to whether a wheel plough or a "swing" plough was best suited to the country. This was decided in favor of the "swing" pattern, since the extra weight and expense of a wheel were avoided, while the advantages which result from a wheel in this country are not so unequivocal as in England. The ridges which form the borders of the irrigation plots in all irrigated fields prevent steady ploughing altogether where a wheel is used, while the advantage of a wheel in transporting the plough to and from the homestead is very doubtful in a country intersected by the numerous watercourses of an Indian village, especially if the plough itself be light enough to be carried on the shoulder.

11. The plough which was finally adopted is a modification of the Watts' plough already mentioned in para. 9 Its weight is only 30lbs., its average draught turning a furrow 5″ × 3½″ on the farm land (which is a rather light soil) is 126lbs., and its price has been brought down to Rs. 6 if fitted with wrought ironwork, while it can be turned out at the Roorkee Foundry with cast ironwork for Rs. 5. Natives will probably prefer wrought ironwork to cast as being more easily repairable. It is fitted with a small cast iron share on a principle which is believed to be a new one, by which the share can be slipped off or on to the frame with great ease. The depth of the furrow can be easily regulated by the length of the rope by which the beam is attached to the yoke. The plough being of so light a weight depends entirely on the correctness of its adjustment for working smoothly and easily, but to regulate the adjustment is a simple matter easily learnt with a few hours practice, and the principle is no new one to native cultivators, who adjust their own ploughs to bullocks of different heights by the use of wooden wedges. Although, before the cattle have become properly trained, an extra man will be needed to drive them, yet as soon as they have become accustomed to the plough the ploughman can easily drive them himself, as is always done now on the farm lands, and in any case the amount of work done by the plough far more than compensates for the wages of a second man.

12. At first ploughs of this description were made up for distribution by a contractor at Cawnpore, and were sold at Rs. 8 a piece. This was not found to work well, and it was determined to start workshops on a small scale in connection with the farm at which ploughs should be made up, and the shares cast under the supervision of the Superintendent. One advantage of this system was the constant opportunity afforded for making fresh improvements which often suggested themselves in the process of construction. Between April 1st and December 31st, 1879, 322 ploughs of the approved pattern, varying a little in details of construction, were made up at the workshops, and, including the ploughs which were previously made up by contract, the total number of ploughs sold during the year is 429, besides 8 more which were given away as samples.

The price of these ploughs has been reduced from Rs. 8 to Rs. 6, since it has been proved that they can be made up at the latter price at a small profit. Messrs. Watts and Co., of Virginia Co., U. S, make a plough still lighter than the one experimented with on the farm, and enquiries have been made from them as to whether they could consent to supply the ironwork alone at wholesale prices. Were this effected and the woodwork fitted to the ploughs at Cawnpore, an implement of far

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better workmanship than can be turned out in India could be supplied to purchasers at a price which would but little exceed the limit of Rs. 8.

13. The opinions which have as yet been received on the ploughs which have been distributed are of the greatest variety. It is satisfactory, however, to note that the opinion of persons who understand the use of English ploughs, is uniformly in favor of the one adopted. Mr. D. N. Reid of Sarun, Tirhoot, who has given an order for 100 of the ploughs to the Roorkee Foundry, writes—"that it is the only plough of a foreign pattern which he has yet seen cultivators inclined to adopt." Mr. C. R. Webb of Dhooly, Tirhoot, states, that "he finds the plough exceedingly useful, and that a number of planters are trying them, and are as well pleased with them as he is." In these provinces, Mr. McConaghey, Collector of Bánda, has used them with great effect in the reclamation of land infected with *kána* grass in villages under direct management. He writes;—"The ploughs are much lighter in draught, more simple in construction, less likely to get out of order, and more easily repaired, and finally plough as deep and as strong as the English* ploughs. Ordinary bullocks can be worked in them, and can plough nearly an acre a day. Deep ploughing, especially in dry years, would greatly increase the produce of the land in Bundelkhand, where we have to depend entirely on the rains. * * I have not encouraged men to buy them. They simply bought them because they thought they suited their purpose." Altogether 51 ploughs have been sent to the Bánda district and have been used there: a large number of these have been bought by cultivators, twelve having been taken in one village.

On the other hand from some districts reports of a discouraging nature have been received, notably from Aligarh and Bulandshahr, each of which rivalled Bánda in the number of ploughs which it purchased. The draught is said to be far beyond the power of the cattle (which in both these districts are exceptionally good), and the efficiency of the plough is to some extent denied. Both of these impressions originate from ignorance of the method of using the plough, of attaching it to the yoke, and of regulating its adjustment. It has been determined in future to distribute no ploughs to native applicants, unless a trained instructor is sent with the ploughs, to explain the mode of using them, and the advantages which result from their use. To supply these instructors, a number of intelligent youths are being trained on the farm under my supervision.

14. It is however on the verdict of the cultivator that the plough depends for its adoption on a large scale, and unfortunately this verdict depends only partially on the real merits or demerits of the implement. In any case, only the most industrious castes of cultivators must be looked to. The gap which divides the good cultivator of this country from the bad, is at least as wide as that which divides the good cultivator from the scientific agriculturalist, and it is impossible to hope that castes which fail to profit by the example of the Kurmis, Lodhis, and Játs in their midst will pay any attention to the teachings of agricultural science. Unfortunately too the persons whom the ploughs generally reach through the district officers, are the very people who must fail most completely to appreciate them, being the prominent zemindars of a district, who are as a rule notoriously indifferent concerning the agricultural condition of their villages.

2. *Waterlifts.*—The experiments which have been conducted during the past half year by Mr. W. J. Wilson, Assistant Engineer, attached to this department, have shown that the efficiency of the ordinary well bucket decreases very rapidly for depths less than 20 feet below the surface, since the repeated emptyings and fillings of the bucket occasion a greater loss of time than is necessary to rest the bullocks. It has therefore been an object to construct a cheap pump, light in weight so as to be easily carried to and from the well, which could lift water from a depth of from 15 to 18 feet more efficiently than this can now be done with bullock labor. The pattern of pump which seemed most suited for this purpose was that kind of chain pump in

* The English ploughs referred to are Messrs. Ransome and Sims', B. F. O.

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which the plugs or suckers fit closely in only the lower portion of the pipe, the upper portion being wider so as to save all unnecessary friction, Pumps constructed on this principle (the *Bastiat* pump) were found serviceable in the Abyssinian war, and the greatly advertised *McComas' waterlift* is merely an adaptation of the same principle. Iron pumps of this description had before this been constructed at Roorkee Canal Foundry for this department and gave admirable results. But the price was prohibitive, so far as cultivators were concerned, being from Rs. 100 to Rs. 120.

A wooden pump has now been constructed which when worked eight hours a day by three men will raise more water from a depth of 14 or 15 feet than can be effected by a pair of bullocks and two men. Its cost is only Rs. 18, but 15 feet is the maximum depth at which it can work, while the iron pump constructed at Roorkee worked effectively up to 20 feet. The subjoined table, summarized from the results of Mr. Wilson's experiments, contrast the actual amount of water raised and the efficiency (in H-P.) of the well bucket at 15′,* and of the wooden water-lift at 14′.

	Height of lift.	*Labour employed.*	*Cubic feet of water raised per hour.*	*Useful work done.* In foot lbs. per minute.	*Useful work done.* In H-P.
Well bucket ...	15′	2 bullocks, 2 men.	269·5	2,102	0·069
Pump	14′	3 men.	304·7	4,436	0 134

In the wooden waterlift experimented with, rope takes the place of chain and hempen knots the place of wood and leather suckers. The wheel and frame are of wood, and a triangular grove running round the circumference of the wheel ensures the "biting" of the rope. The pipe is a split and hollowed bamboo covered with leather for the upper 12 feet; the lower 3 feet, in which the suckers fit closely, being carefully constructed of wood bound with iron. But it is intended to substitute light iron piping for the bamboo, as soon as this can be obtained of the requisite description, and the slight increase in the cost and weight of the pump will be more than counterbalanced by the gain in efficiency.

(iii.)—Experiments on the comparative efficiency of different methods of lifting water.

(iii.)—*Experiments on the comparative efficiency of different methods of lifting water.*

During the first half of the year measurement tanks and wells were completed. The principal one is 10 feet in diameter and 45 feet deep with a floored bottom. It is situated close to the large tank on the garden from which it can be supplied with water to almost any height by a connecting pipe fitted with a sluice gate. Mr. Wilson was therefore enabled to make a series of careful experiments with most of the different methods of lifting water used in this country, as well as with some new methods, the general adoption of which has been advocated. A full account of their experiments and their results, prepared by Mr. Wilson, is appended to this report.

I have, &c.,

J. B. FULLER,

Asst. Director, in charge, Govt. Experimental Farm.

*Unfortunately the two experiments were not at exactly the same depth, and the results must be therefore accepted as giving only an approximate idea of the relative efficiency of the well bucket and pump.

APPENDIX.

Report on experiments with different waterlifts by MR. W. J. WILSON, C.E.

Note by Mr W. J Wilson, Asst. Engineer.

1. THE object of the experiments now in progress is to determine the cheapest and best method of raising water under any given circumstances. With this view the discharges of some of the water-lifts ordinarily used in this country and of some pumps lately introduced have been tested when working at different depths. The results of these experiments are given in the accompanying tables.

2. Some of the terms used in the tables may require explanation. The action of a machine is expressed by multiplying the resistance overcome by the distance moved through; the product being called *work*. Thus, the work done in raising a weight of one lb. through a height of one foot is one *foot-pound;* the work done in raising a weight of one ton through a height of one foot is one *foot-ton ;* the work done in raising the weight of a cubic foot of water (=62 4lbs) through a height of ten feet is 624 foot-pounds. The rate of work of a machine may be expressed in units of work (such as foot-pounds) per second, per minute, or per hour. But there is a peculiar unit appropriated to its expression called a *horse-power* (H-P) which is equivalent to 33,000 of power foot-pounds per minute or 1,980,000 foot-pounds per hour.

3. The work done by a machine is divided into *useful work* and *lost work*. The *useful* work of a machine is that which is performed in effecting the object for which the machine was designed ; the *lost* work is that which is performed in overcoming prejudicial resistances, such as friction. The useful work and the lost work of a machine together make up its total or gross work. For example, in a chain pump worked by men turning a crank, the total work done by the men upon the pump in a given time is the mean effort exerted by the men upon the crank multiplied by the distance described by the crank in that time; the useful work is the weight of water raised in that time multiplied by the height to which it is raised; the lost work, or difference between the total work and useful work; is expended in overcoming the friction between the plugs and the pipe, the friction between the water and the pipe, and the friction between the axle of the wheel and its bearings, and in raising water which leaks down again between the plugs and pipe. In the annexed tables only the *useful work* is shown. The *efficiency* of a machine is a fraction expressing the ratio of the useful work to the total work performed.

4. The best units of work for expressing the action of waterlifts are the cubic foot of water raised one foot high and the foot-ton. The former is easily calculated, the discharge of a waterlift being usually given in cubic feet per second or per minute. The quantity of water required to flood an acre of land to a depth of one inch is nearly 100 tons (accurately 101 27.) If the average depth of a watering is 2½ inches, 250 tons of water will be required at each watering, mutiplying this by the height to which the water is lifted we obtain the number of foot-tons of useful work that must be performed by the waterlift to irrigate one acre of land. If the number of foot-tons performed per hour and the cost per foot-ton are known, the time required to irrigate an acre and the cost of the irrigation can be obtained.

5. The following results of the work done by horses, men, and oxen working eight hours daily in England, are taken from Rankine's Treatise on the Steam Engine.

Kind of exertion.	Foot pounds per minute.	Horse-Power.	Foot-tons daily
Horse, drawing a cart or boat, walking ...	25,920	0 785	5,554
Horse, drawing a gin or mill, walking ...	18,000	0 545	3,857
Man, turning a crank or winch	2,700	0·082	579
Ox, drawing a cart or boat walking (⅔ of power of a horse)	17,280	0 524	3,703
Ox, drawing a gin or mill, walking	12,000	0 363	2,571

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A pump may be worked by men turning a crank or by oxen working a gin: if the *efficiency* of the machine is 0·6, the useful work performed in the two cases will be as follows:—

Kind of exertion.	Foot-pounds per minute.	Horse-power.	Foot-tons daily.
Man, working a pump by turning a crank (2,700 × 0·6)	1,620	0·049	347
Ox, working a pump by turning a gin (12,000 × 0 6)	7,200	0 218	1,543

6. At the Cawnpore Experimental Farm the discharges of the following water-lifts have been tested:—

(i.) lifts worked by manual labour—

a.—the basket or *beri* (heights of lift 1′·5 to 6′);

b.—*dhenkli* (height of lift 15 feet);

c.—chain pumps (height of lift 10·5 to 15 feet).

(ii) lifts worked by bullock labour—

a.—single *moth* and inclined bullock run (height of lift 15 to 50 feet);

b.—double *moth* worked by ropes passing round a drum on a vertical axis, (height of lift 45·5 feet);

c.—chain pump (height of lift 39 feet).

The quantity of water raised was measured in masonry tanks.

7. The results of experiments with the basket are shown in table I. Three men were employed to work the basket; one man resting, while two worked; but the laborers said that four men would be required to keep it going eight or nine hours daily. Two series of experiments were made, the same men being employed throughout each series (except in i. *a.*, when one of the men was changed). As the height of lift decreases, the quantity of water lifted at each throw and the number of throws per minute increase, the former more rapidly than the latter. In the first series of experiments the basket was most effective (as a machine) for lifts of 5 and 4 feet; in the second series for lifts between 3½ and 5 feet. Between these lifts the rate of work performed was nearly 70 foot-tons per hour.

8. In a note on wells (Famine replies) Mr. Buck states that with two 3 feet baskets lifts, six men can irrigate one acre a day. Hence four men can irrigate two-thirds of an acre (= 29,040 sqr. feet) a day. The mean of experiments 3 and 7 *a* give 839·7 cubic feet of water raised by a three feet basket lift per hour. In a day of eight hours four men would raise 839·7 × 8 = 6,717·6 cubic feet. If this were used to irrigate two-thirds of an acre the depth of the watering would be $\frac{6717\cdot6}{29040}$ = 0·23 feet. This is very near the mark, experiments on well irrigation having given about 2½ inches as the depth of a watering.

9. With the *dhenkli* only one experiment (table III, No. 8) has been made at the Cawnpore Farm. This apparatus is very commonly used for irrigation in the Moradabad district, and I tested one at Bachhraon on the 24th November. The results obtained were as follows:—

Height of lift ... ... 13′·25

Capacity of earthen vessel (*karwála*)—0·25 cubic feet = 1·56 gallons.

Number of times the karwála was raised per hour = 311.

Quantity of water raised per hour = 77·8 cubic feet = 4,854·7 lbs.

Useful work performed per minute = 1,076·1 foot-pounds.

Ditto ditto per hour = 28·8 foot-tons.

Ditto ditto per day of 8 hours = 230·4 foot-tons.

Rate of useful work performed = 0·033 H-P.

One man was employed to work the *dhenkli*, and he worked for four hours without stopping. Two men are usually employed during the day, one raising the water and the other looking after its distribution, but the people at Bachhraon told me that one man could work the apparatus for eight hours a day.

Note by Mr. W. J. Wilson, Asst. Engineer.

10. Table II. gives the results of 9 trials with a 2½ inch iron chain pump for 15 feet lift made at Roorkee.

The trials lasted only a short time, and do not give the rate of work that can be kept up daily. I think, however, that four men working eight hours a day can lift 300 or 320 cubic feet an hour to a height of 14·5 feet. The power of the four men usefully applied would then be represented by—

$$\frac{300 \times 62\cdot4 \times 14\cdot5}{60 \times 33{,}000} = 0\cdot137 \text{ H-P.}$$

I have used these figures in Table VII. to find the cost of work performed by the pump. Experiments 6 to 9 (Table II.) were made to determine the leakage between the plugs and the pipe at different speeds; this varied from 150 to 167 cubic feet per hour, and is fairly uniform for all the speeds tried. The efficiency of the pump therefore increases with the speed of the chain.

11. Table III. gives the results of trials with other pumps. Trials 1 to 3 were with a 2¼ inch McComa's chain pump for 12 feet lift from Melbourne. The rate of useful work performed varied from 0·149 to 0·157 H-P, the trials lasting only a short time. These results could not be maintained throughout the day, but the average power of four men working eight hours daily would probably be about the same as is obtained in the last paragraph for the same sized pump with a higher lift, or 0·137 H-P.

12. Trials 4 to 7 were with cheaply constructed pumps made up at the Experimental Farm on the principle of the chain pump, rope being substituted for chain, and wooden pipe or hollowed-out bamboo for the iron pipe. The power of three men varied from 0·106 to 0 134 H-P usefully applied, and I think that 0·100 to 0 105 H-P could be maintained throughout the day. In experiments 4 and 5 the plugs were considerably worn and worked loose in the pipe; in experiments 6 and 7 they fitted more tightly. Owing to the difficulty of getting large bamboos the bore of the pipe was made only 2¼ inches, and the pump can be worked by three men. If the bamboo is replaced by galvanised sheet iron piping a larger bore can be used and the weight will be very little if at all increased.

13. Table IV. gives the results of experiments made with the single *moth* and inclined run on one of the wells in the Experimental Farm: the experiments were arranged by Mr. W. R. S. Jones, Executive Engineer, in order to find the average amount of work done by one bullock or buffalo. Ten trials were made with bullocks, using a fresh pair every day; four trials were also made with four pairs of buffaloes. The *moth* used in these experiments contained 13·95, or nearly 14 gallons, and was smaller than is generally used. Mr. Wright, C.S., states that in the Cawnpore district the *moth* contains from 14 to 18 gallons. The buffaloes could probably have worked with a *moth* containing 28 or 30 gallons. The means of the 10 experiments with bullocks and of the 4 with buffaloes give very similar results; the power, usefully applied, of one bullock being 0·065 H-P, and that of one buffalo 0·086 H-P. With a larger *moth* the rate of work would have been higher.

14. To compare the quantities of water raised by a pair of bullocks from different depths, eight experiments, the results of which are given in Table V., were made on the blind well at the experimental farm. This well is connected by a sluice with an earthen tank containing water, so that the water in the well can be kept at any required depth from 13 feet to 45 feet below the top of the steining. During the first six experiments a *moth* was used containing about 17 gallons; it burst after the 6th experiment, and was replaced by another containing nearly 21 gallons. The same bullocks were used throughout the experiments.

Note by Mr W. J. Wilson, Asst Engineer

15. The quantity of water lifted per hour decreases as the height o lift increases, but not in the same proportion. With a 15 feet lift the discharge was 269·5 cubic feet per hour, and with a 40 feet lift 195 5 cubic feet per hour. The rate of useful work done increases as the height of lift increases: with a 15 feet lift it was 0 064 H-P., while with a 40 feet lift it was 0·130 H-P. These experiments are incomplete, as they do not give the number of hours that the bullocks can work daily at the rates observed. If with a 15 feet lift the bullocks can work eight or nine hours daily, with a 40 feet lift they may be unable to work more than six hours a day. Complete statistics can be best obtained by recording the quantities of water raised from wells working constantly during the irrigating season. But I think there is no doubt that this method of raising water with single *moth* and inclined bullock-run becomes more effective as the depth of water below the ground increases.

16 An experiment with the double *moth* worked by ropes passing round a drum on a vertical axis gave the following results:—

One buffalo was employed—

Height of lift averaged	...	...	...	45 5 feet
Contents of *moth*	...	...	...	2·54 cubic feet. (=157 8 lbs.)

Duration of experiment=3 hours.
No. of *moths* lifted per hour=34⅓.
Discharge per hour=87·2 cubic feet (=5·441 lbs.)
Useful work per hour=247,579 foot-lbs.=101·6 foot-tons
Useful work per minute=4,126 foot-lbs.
Rate of useful work=0 126 H-P.

Four trials with buffaloes working the single *moth* gave the rate of useful work performed by one buffalo when height of lift was 49′8=0 066 H-P (Table IV) but as mentioned above, the *moth* used was much too small. An experiment on the blind well (Table V.) gave the rate of useful work when height of lift was 45′=0 130 H-P.

17. On the 24th November, I tested a double *moth* apparatus erected by Mr. D. M. Smeaton, C.S., at Bachhraon in the Moradabad district. Three trials were made, and the results are recorded in Table VII During the first two trials the apparatus was worked by a single bullock, larger and more powerful than those generally kept by cultivators: the pair of bullocks used in the third trial were similar to those commonly used for ploughing and irrigation. The useful work performed in the three trials was nearly equal. The owner of the well stated that the bullocks could work six hours daily, but required to be relieved every three hours.

18. A 3 inch McComa's chain pump from Melbourne has been erected on the blind well and tried with the following result:—

Height of lift—39 feet.
Animals employed—two pairs of bullocks.
Duration of trial=87 minutes.
Discharge per hour=156 3 cubic feet.
Useful work per hour=380,372 foot-lbs =169·8 foot-tons.
Useful work per minute=6,340 foot-lbs.
Rate of useful work=0·192 H-P.
Rate of useful work per bullock=0 048 H-P.
Speed of chain=2·21 per feet per second.
Quantity of water that leaked back again between plugs and pipe per hour=218 9 cubic feet.

Experiments 6 to 9 of Table II. gave the loss by leakage in a 2½ inch chain pump worked by hand equal to about 160 cubic feet per hour, when the height of lift was 14 80 feet. Allowing for the increase in the diameter of the pipe and in height of lift

the loss by leakage in the large pump was less than in the small one. The four experiments with the latter show that it is not effective when the speed of chain is less than four feet per second, and the same may be said of the larger pump. It will never supersede the *moth* for bullock power for lifts greater than 20 or 30 feet; but would give good results for high lifts if worked by steam-power, as the chain could then be driven at a greater speed.

Note by Mr. W. J. Wilson, Asst. Engineer.

19. Table VI. gives the results recorded on some wells working daily during the irrigating season. Commissariat bullocks were used in No. 1, and gave much higher results than have been obtained with ordinary bullocks. No. 2 was recorded by Mr. Beresford, Executive Engineer. No. 3 is the result of numerous experiments by Mr. F. N. Wright, C. S., in the Cawnpore district. The capacity of the *moth* is said to vary from 14 to 18 gallons, so I have used a mean value of 16 gallons or 160 lbs. No. 4 is from data furnished by the Collector of Agra; a large *moth* containing 34 gallons being used, bullocks of corresponding strength are required to raise it; the rate for hiring these bullocks is 14 annas a pair per diem. Nos. 5, 6 and 7 were recorded at the Government Horticultural Gardens, Lucknow; here also large bullocks are used, and the tate for hiring them would be about 12 annas a pair. No. 8 was recorded at the Shikohabad Railway Station with an exceptionally high lift, and is the mean of three days working.

20. In all the experiments at the experimental farm only one pair of bullocks at one time were employed to raise the *moth*, the system adopted in the Meerut and Aligarh districts of using two pairs of bullocks and a side run being apparently unknown in the neighbourhood of Cawnpore. Of the trials recorded in Table VI., Nos. 1, 3, 5, 6, 7 and 8 were made with single pairs of animals, while in Nos. 2 and 4 two pairs of animals were used to one *moth*.

21. The following results obtained by the Persian wheel have been furnished by Mr. Sturt, Assistant Commissioner of Jhánsi.

Height of lift, 20 feet.
Discharge for one revolution, 160 lbs.
Number of revolutions per minute, $1\frac{1}{2}$.
Discharge per hour = 205 cubic feet.
Useful work done per minute = 4,267 foot-lbs.
Rate of useful work = 0·128 H-P.
Useful work per hour = 114·2 foot-tons.
One pair of bullocks can work this for six hours a day.

22. In Table VIII. the cost of the useful work performed by different water-lifts is obtained. To make the comparison complete, allowances should be made for the interest on the original cost of the lift, and for repairs and depreciation, but I have not sufficient *data* to do this. The chain pump for manual labour when lift is from 10 to 15 feet is decidedly more effective than the basket or *beri*. The *dhenkli* is also an effective apparatus for low-lifts, but, as generally worked, the cost is greater than that shown in the tables; one man being required for the distribution of the water and another to work the *dhenkli*. The two men take each work in turns for about 10 hours a day, so that each man actually lifts the water for only five hours a day. As regards the single and double *moth* for bullock-power the records obtained from wells in actual work are too few to pronounce definitely, but the trials made show that when the height of lift is about 20 feet the double *moth* is considerably cheaper to work than the single *moth*. Arrangements are in progress to work the two systems side by side, and with similar bullocks at places where irrigation is almost constantly going on. With the single *moth*, as the height of lift increases the cost of the useful work performed decreases, a result that was anticipated in para. 15. The capacity of the leather bucket or *moth* varies from 14 to 36 gallons, and is regulated by the strength of the animals employed.

Note by Mr W. J. Wilson, Asst. Engineer.

23. The city of Jaipur is supplied with water from a stream 2½ miles distant, the water being pumped up by steam-power to a height of 120 feet. The total cost of the waterworks was 4½ lakhs, but omitting the cost of pipes, &c, for taking the water from the pumping station to the city, the expenditure was nearly as follows:—

	Rs.
Weir in river	8,578
Pumps	73,575
Engine house, &c.	16,557
Boilers	34,138
Boiler house	5,775
Service reservoirs	43,235
Workshop and godown	5,259
Miscellaneous, say	10,000
Establishment, say	5,000
Total ...	2,02,177
Interest on original expenditure at Rs. 5 per cent.	10,109
Maintenance for one year	26,253
Depreciation at Rs. 3 per cent. on engine, pumps, boilers and workshops (Rs. 1,29,529)	3,886
Total cost for one year ...	40,248

Average quantity of water raised daily for one year = 310 512 gallons.

Useful work done daily = 3,105,120 × 120

= 372,614,400 foot-lbs.

= 166,345 7 foot-tons.

Cost of 1,000 foot-tons of useful work is $= \frac{40,248 \times 16 \times 1,000}{166,345 \cdot 7 \times 365} = 10 \cdot 6$ annas.

Major Jacob states that the cost of maintenance is high owing to the high price of coal, which delivered at Jaipur costs Rs. 40 a ton. At Cawnpore coal can be obtained for Rs. 20 a ton, and the yearly charge for maintenance would be reduced by Rs. 9,465. The cost of 1,000 foot-tons of useful work, including maintenance and interest charges, would then be reduced to 8·1 annas. (*The above details have been taken from a paper by Major Jacob in the Professional Papers on Indian Engineering.*)

24. Comparing the results given in para. 5 for English oxen and men with those obtained in the tables, it will be noticed that the former are much greater than the latter. A native working a chain pump eight hours daily can perform ($\frac{968}{4}$ =) 242 foot-tons of useful work (Table VII.), while an Englishman would do almost 347 foot-tons or nearly half as much again. The difference between the cattle is still greater, the useful work performed by a pair of the large bullocks employed to irrigate the Táj garden being no greater than should be perfomed by a single ox in England.

25. A fan in the agricultural workshops is worked by a pair of bullocks turning a gin. Average draught measured by indicating dynanometer about 100 lbs. speed of bullocks = 113·2 feet per minute.

Working hours per day, 10.

Gross work done by a pair of bullocks turning a gin = 113·25 × 100 × 60 × 10

= 6,795,000 foot-lbs.

= 3,033 foot-tons.

From para. 5 the total work done daily by one English ox turning a gin is seen to be 2,571 foot-tons.

W. J. WILSON,
Assistant Engineer.

Table I.—Showing results of trials with the basketlift at Cawnpore Experimental Farm.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Number of experiment.	Date.	Height of lift.	Duration of experiment.	Number of baskets lifted.	Quantity of water lifted.	Quantity of water lifted by one basket.		Number of times the basket was lifted per minute	Quantity of water lifted				Useful work done by three men working one basket					Remarks.
									Per minute.		Per hour.				In one hour.			
						In cubic feet.	In pounds		Cubic feet.	Pounds.	Cubic feet	Pounds.	Foot-pounds per minute.	Horse-power.	Foot-pounds	Foot-tons	Cubic feet of water raised one foot high.	
			Minutes		Cubic feet.													
1	12th September ...	5′	70	1,412	510 5	0·36	22 6	20·2	7·29	455·1	437 4	27,306	2,275·4	0 069	1,36,524	60·95	2,187	All these experiments were made by the same three men.
2	14th ditto ...	4′	45	949	487 3	0 51	32 8	21·1	10·82	675 7	649 2	40,542	2,702·9	0 082	1,62,174	72·40	2,597	
3	15th ditto ...	3′	35	801	520·0	0·65	40·5	22 9	14 86	927·1	891 6	55,626	2,781·3	0 084	1,66,878	74 50	2,675	
4	Ditto ...	2′	30	726	491·5	0 68	42·2	24 2	16 39	1,022 3	9·834	61,388	2,044·6	0·062	1,22,676	54 77	1,967	
5	Ditto ...	1·5′	27	682	527·4	0 77	48 3	25 3	19 53	1,218·9	1,171 8	73,134	1,828·3	0·055	1,09,698	48 97	1,758	
1a	4th October ...	6 0′	90	1710	436 6	0 25	15 9	19·0	4 85	302·7	291·1	18,162	1,816·2	0·055	1,08,973	48 65	1,747	One set of men employed in all these experiments except No. 1a, in which one of the men was changed
2a	Ditto ...	5 5′	80	600	177·2	0·30	19·7	20·0	5·91	368·8	354·6	22,128	2,028·3	0·061	1,21,698	54 33	1,950	
3a	27th September ...	5·′	60	1,237	491·9	0·40	24·8	20 6	8 20	511 6	492 0	30,696	2,557·9	0·0775	1,53,474	68 52	2,460	
4a	Ditto ...	4·′5	50	1,082	467·2	0·43	26·9	21 6	9·34	583 1	560·4	34,986	2,623·8	0 0795	1,57,328	70·24	2,522	
5a	28th ditto ...	4′	45	972	465 1	0 48	29·9	21·6	10 34	644 9	620·4	38,694	2,579·8	0 078	1,54,788	69 10	2,482	
6a	Ditto ...	3′5	40	874	469 4	0·54	33·5	21·9	11·74	732 3	704·4	43,938	2,562·9	0·078	1,53,774	68·65	2,465	
7a	29th ditto ...	3′	40	921	525·2	0·57	35·6	23 0	13 13	819·3	787·8	49,158	2,457·9	0·074	1,47,474	65 84	2,363	
8a	Ditto ...	2′ 5	35	828	477·8	0·58	36·0	23·7	13 65	851·8	819 0	51,108	2,129·6	0 065	1,27,776	57 04	2,048	
9a	30th ditto ...	2′ 0	35	867	529 5	0·61	38 1	24·8	15·13	944·0	907 8	56,640	1,888·0	0·057	1,13,280	50·06	1,816	
10a	1st October ...	1′·75	30	776	472·5	0 61	38 0	25·9	15 75	982·8	945·0	58,968	1,719 9	0 052	1,03,194	46·03	1,654	

Note by Mr W. J Wilson, Asst. Engineer.

Note by
Mr. W. J. Wilson,
Asst. Engineer.

Table II.—Showing results of trials with a two and a half inch iron chain pump for 15 feet lift.

Number of experiment.	Date.	Height of lift.	Duration of experiment.	Quantity of water discharged.	Discharge per hour.		Number of men employed.	Useful work done.			Speed of chain in feet per minute.	Quantity of water lost by leakage in cubic feet per hour.	Sum of actual discharge and water lost by leakage per hour.	Percentage lost by leakage.
					In cubic feet.	In lbs.		Foot-lbs. per minute.	Foot-lbs. per hour.	Horse-power				
			Minutes.											
1	August 5th, 1879 ...	14′·50	30	221·5	443	27,643	3	6,680	400,826	0·20	Not noted...	...	...	...
2	Ditto 6th, „ ...	14′·50	60	401·0	401	25,022	3	6,047	362,824	0·18	Do. ...	...	...	...
3	October 1st, „ ...	14′·50	20	130·9	392·7	24,504	3	5,922	355,315	0·18	Do. ...	...	...	...
4	Ditto 2nd, „ ...	14′·80	80	499·9	375·0	23,400	4	5,772	346,320	0·17	Do. ...	...	...	...
5	Ditto, „ ...	14′·80	80	514·7	386·0	24,086	4	5,941	356,479	0·18	Do. ...	...	...	...
6	Ditto 3rd, „ ...	14′·80	80	428·2	321·2	20,043	4	4,944	296,619	0·15	4·16	158·1	479·3	33
7	Ditto, „ ...	14′·80	60	52·7	52·7	3,288	2	811	48,670	0·025	1·84	160·1	212·8	75
8	Ditto, „ ...	14′·80	5	*Nil.*	*Nil.*	*Nil.*	2	*Nil.*	*Nil.*	*Nil.*	1·24	150·4	150·4	100
9	Ditto, „ ...	14′·80	30	215·4	430·8	26,882	4	6,681	397,852	0·21	5·17	167·4	598·2	28

Table III.—Showing results of waterlifts worked by manual labour at the Cawnpore Experimental Farm.

1	2	3	4	5	6	7	8	9	10	11	12	13
							Discharge per hour.		*Useful work done.*			
No. of experiment.	Date.	Description of pumps.	Number of men employed.	Height of lift.	Duration of experiments.	Discharge during experiment in cubic feet	In cubic feet.	In lbs.	In foot-pounds per minute.	In foot-pounds per hour.	Horse-power	Remarks.
	1879.				Minutes.							
1	August 1st...	McComa's chain-pump 2½″ diameter ...	3	10″90	40	303 8	455·7	28,436	5,166	309,949	0·157	
2	„ 2nd...	Ditto ditto	3	11·″10	30	236·25	472 5	29,484	5,455	327,272	0 165	
3	„ 6th...	Ditto ditto	4	11·″50	60	410 0	410·0	25,584	4,904	294,216	0·149	
4	„ 4th ...	Wooden chain-pump 2¼″ diameter ...	3	14′	65	270·0	249·2	15,550	3,628	217,701	0·110	
5	„ 5th ..	Ditto ditto	3	14′	90	360·0	240·0	14,976	3,493	209,654	0 106	
6	„ 12th...	2¼″ chain-pump with bamboo pipe ...	3	14′	54	274·2	304·7	19,013	4,436	266,186	0 134	
7	Octr. 2nd...	Ditto ditto	3	14′40	90	375 0	350·0	15,600	3,744	224,640	0 113	
8	„ 5th...	*Dhenkli*	1	15	180	186 0	62·0	3,869	956	57,332	0 029	Iron bucket contained 0·34 cubic feet. Number of lifts per hour = 61½

Note by Mr. W. J. Wilson, Asst Engineer.

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Note by
Mr. W. J. Wilson,
Asst. Engineer.

Table IV.—Showing results of trials with single "moth" and inclined bullock-run on a well at Cawnpore Experimental Farm.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	
		Animals employed.				*Quantity of water lifted by one moth.*			*Quantity of water lifted per hour.*		USEFUL WORK DONE BY ONE BULLOCK OR BUFFALO.					
													In one hour.			
No. of experiment.	Date.	Kind.	No.	Height of lift.	Duration of experiment.	In cubic feet.	In pounds.	Number of moths lifted per hour.	Cubic feet.	Pounds.	Foot-pounds per minute.	Horse-power.	Foot-pounds.	Foot-tons.	Cubic feet of water raised one foot high.	Remarks.
	1879.				Hours.											
1	April 1 ...	Bullocks ...	2	49′ 2″	4	2·235	139·5	29	64·8	4,046	1,658	0·050	99,451			
2	" 2 ...	Do. ...	2	49′·2″	5	"	"	27	60·3	3,767	1,543	0·047	92,591			
3	" 2 ...	Do. ...	2	49′·8″	4½	"	"	45	100·6	6,278	2,599	0·079	155,898			
4	" 3 ...	Do. ...	2	49′ 2″	3	"	"	33	73·7	4,604	1,886	0·057	133,167			
5	" 4 ...	Do. ...	2	49′·2″	3	"	"	32	71·5	4,464	1,829	0·055	109,739			
6	" 7 ...	Do. ...	2	49′ 6″	3	"	"	42	93·9	5,859	2,417	0·073	145,011			
7	" 8 ...	Do. ...	2	49′ 8″	3	"	"	38	84·9	5,301	2,194	0·066	131,647			
8	" 10 ...	Do. ...	2	49′·8″	3	"	"	40	89.4	5,580	2,310	0·070	138,577			
9	" 11 ...	Do. ...	2	49′ 8″	3	"	"	46	102·6	6,417	2,556	0·080	159,364			
10	" 16 ...	Do. ...	2	49′·8″	3	"	"	43	96·1	5,999	2,483	0·075	148,971			
	Average of ten experiments		2	49′·5″½	...	2,235	139·5	37·5	83·9	5,235	2,158	0·065	129,432	57·8	2,074	
11	April 14 ...	Buffaloes ...	2	49′ 8″	3	2·235	139·5	43	96·1	5,999	2,483	0·075	148,971			
12	" 18 ...	Do. ...	2	49′·8″	2½	"	"	43	96·1	5,999	2,483	0·075	148,971			
13	May 9 ...	Do. ...	2	49′ 8″	3	"	"	30	67·0	4,185	1,732	0·052	103,932			
14	" 11 ...	Do. ...	2	49′·8″	3	"	"	34	76·0	4,743	1,965	0·060	117,791			
	Average of four experiments		2	49′·8″	...	2·235	139·5	37·5	83·8	5,231	2,166	0·066	129,916	58·0	2,082	

Table V.—Showing results of trials with single moth and inclined bullock-run on the blind well at Cawnpore Experimental Farm.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Number of experiments.	Date.	*Animals employed.*		Height of lift.	Duration of experiment.	*Quantity of water lifted by one moth.*		Number of moths lifted per hour.	*Quantity of water lifted per hour.*		Useful work done by one bullock.					Remarks.
		Kind.	Number.			Cubic feet.	Pounds.		Cubic feet.	Pounds.	Foot-pounds per minute.	Horse-power.	*In one hour.* Foot-pounds.	Foot-tons.	Cubic feet of water raised one foot high.	
				Feet.	Hours.											
1	4th September, 1879,	Bullocks...	2	15	3	2·66	165·9	101½	269·5	16,815	2,102	0·064	1,26,114	56·3	2,022	
2	6th ditto ...	Ditto ...	2	20	3	2·73	170·4	79	215·7	13,460	2,244	0·068	1,34,602	60·1	2,157	
3	7th ditto ...	Ditto ...	2	25	3	2·76	172·2	79⅔	219·9	13,722	2,857	0·087	1,71,529	76·6	2,749	
4	8th ditto ...	Ditto ...	2	30	3	2·76	172·2	69⅔	192·3	11,998	3,000	0·091	1,79,974	80·3	2,885	
5	9th ditto ...	Ditto ...	2	35	3	2·76	172·2	71	196·0	12,228	3,567	0·108	2,13,989	95·5	3,430	
6	11th ditto ...	Ditto ...	2	40	3	2·70	168·7	72½	195·5	12,201	4,067	0·123	2,44,019	108·9	3,910	
7	12th ditto ...	Ditto ...	2	40	3	3·34	208·2	61½	204·7	12,772	4,258	0·129	2,55,446	114·0	4,094	
8	13th ditto ...	Ditto ...	2	45	3	3·34	208·2	55	183·6	11,453	4,295	0·130	2,57,703	115·0	4,131	

Note by Mr. W. J. Wilson, Asst. Engineer.

Note by Mr W. J. Wilson, Asst Engineer.

Table VI.—Records of results obtained with the single moth and inclined bullock-run when irrigation was in progress.

Number.	Height of lift.	Labor employed.		Number of working hours in a day.	Quantity of water lifted by one moth.		Number of moths lifted per hour.	Quantity of water lifted per hour.		Number of moths lifted during the day.	Quantity of water lifted during the day.		Useful work performed.				Remarks.
		Animals.*	Men at 2 annas.		Cubic feet.	Pounds.		Cubic feet.	Pounds		Cubic feet.	Tons.	In foot-pounds per minute.	Horse-power.	In foot-tons. Per hour.	In foot-tons. Per day.	
1	35′	2 bullocks (Commissariat) ...	1	6	4·73	295·2	66·7	315·4	19,681	400	1,892	52·7	11,481	0 35	307	1,845	Commissariat mills, Cawnpore.
2	30′	4 buffaloes at 4 annas ...	1	10	5·34	333·2	41·7	222·7	13,896	417	2,227	62 0	6,948	0 21	186·0	1,860	Recorded by Mr J. S. Beresford, Executive Engineer at Atrauli.
3	40′	2 bullocks at 4 „ ...	1	8 75	2 56	160·0	40 0	102·4	6,400	350	896	25·0	4,266	0·13	114·2	1,090	Recorded by Mr F. N. Wright, C.S., in Cawnpore district.
4	50′	4 ditto at 7 „ ...	1	10	5·45	340·0	40·0	218·0	13,600	400	2,180	60·7	11,336	0·34	303 6	3,035 7	Táj gardens, Agra.
5	17′ 5	2 ditto at 6 „ ...	1	9	3·00	187·2	68·3	204·9	12,787	615	1,845	51·4	3,730	0 11	99 9	899·5	Lucknow Horticultural gardens.
6	22′·0	2 ditto at 6 „ ...	1	9	3·00	187·2	63·0	189 0	11,794	567	1,701	47·4	4,521	0·14	121·1	1,090·0	Ditto ditto.
7	25′·0	2 ditto at 6 „ ...	1	9	3·00	187·2	55·8	167·4	10,446	502	1,506	42 0	4,353	0 13	116·6	1,049·0	Ditto ditto.
8	68′·0	2 buffaloes at 4 „ ...	1	6	5·76	355·7	28·75	163 9	10,226	173	996	27 8	11,589	0 35	314 8	1,888 7	Recorded at Shikohabad.

* Pay of bullock driver included in the rate allowed for the animals.

Table VII.—Showing the results of three trials with a double-moth apparatus, erected by Mr. Smeaton, C.S., in the Moradabad district.

Number.	Date.	Height of lift.	Animals employed.	Duration of experiments.	Quantity of water lifted by one bullock.		Number of moths lifted in one hour.	Quantity of water lifted in one hour.		Number of working hours in a day.	Number of moths lifted during day.	Quantity of water lifted during the day.		Useful work performed.				Remarks.
					Cubic feet.	Pounds.		Cubic feet.	Pounds.			Cubic feet.	Tons.	In foot pounds per minute.	Horse-power.	In foot-tons. Per hour.	In foot-tons. Per day.	
				Hours.														
1	24th November ...	20′·71	1 bullock ...	3	2·96	184·7	97⅓	288·1	17,978	6	584	1,729	43·2	6,205	0·188	166·2	997·2	
2	Ditto ...	21′·90	1 ditto ...	3	2·96	184·7	90⅓	267·4	16,685	6	542	1,604	44·7	6,090	0·185	163·1	978·8	
3	Ditto ...	20′·50	2 ditto ...	3	2·96	184·7	92½	273·3	17,055	6	554	1,640	45·7	5,827	0·177	156·1	936·5	

In the first two trials the apparatus was worked by single bullocks larger and more powerful than those generally kept by cultivators; the bullocks used in the third trial were similar to those commonly used for ploughing and irrigation.

Note by Mr. W. J. Wilson, Asst. Engineer.

Note by
Mr. W. J. Wilson,
Asst. Engineer.

Table VIII.—Showing cost of work done by different waterlifts.

Number.	Kind of waterlift.	Height of lift.	Labor employed.		Number of working hours in a day.	Cost of labor.		Useful work performed.		Cost of useful work performed.		Remarks.
			Bullocks* or buffaloes at 8 annas per pair.	Men at 2 annas.		Per day.	Per hour.	Pounds.	Foot-tons daily.	1 horse-power per hour.	1,000 foot-tons.	
						Annas.	Annas.					
1	Basket or *beri*	3′ to 4′·5	...	4	8	8	1·0	0·080	565·4	12·5	14·1	See table I.
2	*Dhenkli*, or lever-lift	13′	...	1	8	2	0·25	0·033	230·4	7·6	8·7	„ „ III., No. 8.
3	Chain pump	10′·5 to 15′	...	4	8	8	1·0	0·137	968·8	7·3	8·2	„ para. 10.
4	Single moth and inclined bullock-run ...	68′	2	1	6	10	1·67	0·35	1,888·7	4·8	5·3	„ table VI., No. 8.
5	Ditto ditto ditto ...	50′	†4	1	10	30	3·0	0·344	3,035·7	8·7	9·9	„ „ „ „ 4.
6	Ditto ditto ditto ...	40′	2	1	8·75	10	1·14	0·130	1,000·0	8·8	10·0	„ „ „ „ 3.
7	Ditto ditto ditto ...	30′	4	1	10	18	1·8	0·210	1,860	8·6	9·6	„ „ „ „ 2.
8	Ditto ditto ditto ...	20′	‡2	1	9	14	1·6	0·150	1,000·0	12·3	14·0	„ „ Nos. 5, 6 and 7.
9	Double moth	20′ to 22′	2	...	6	8	1⅓	0·179	950	7·4	8·4	„ table VII.
10	Persian wheel	20′	2	..	6	8	1⅓	0·128	685·8	10·4	11·7	„ para. 21.

* The pay of the driver of the bullocks is included in the rate given.
† These bullocks cannot be hired for less than 14 annas a day.
‡ Ditto ditto 12 annas a day.

ORDER OF GOVERNMENT.

No. 1252 of 1880.

From

The SECRETARY to GOVERNMENT,
N.-W. Provinces and Oudh,

To

The DIRECTOR, DEPT. of AGRI. and COMMERCE,
N.-W. Provinces and Oudh.

Dated Naini Tal, the 19th July, 1880.

Revenue Department

Sir,—I am directed to acknowledge your letter, No. 341A., dated the 5th June, with which was submitted the annual report on the Government Experimental Farm, Cawnpore, for 1878-79, drawn up by Mr. Fuller, together with Mr. Buck's review thereon.

2. The report, while it gives an interesting account of the experiments with ploughs and water-lifts, contains no allusion to the state of the farm and farm operations proper, and sketches out no programme for the future.

3. The reason given is that the late Superintendent, though coming with a high character, was found to have systematically neglected orders from the very commencement. An inquiry made in October ended in his resignation on the 1st November, from which date Mr. Fuller assumed charge. Agricultural operations are therefore entirely put aside, as the results professed to have been obtained were obviously not to be depended on. But Mr. Fuller might have given an account, however brief, of the crops actually grown, the objects aimed at, and their general success or failure, irrespective of an accurate record of results. The condition of the farm and its appurtenances when he took over charge should also have been placed on record, and the nature of the late Superintendent's shortcomings might have been explained, *i.e.*, whether he merely neglected to record results as directed, or misconducted operations. It should also have been stated what is to be done in future, and a balance-sheet, showing the receipts and expenditure of the year, and how the accounts stand, should certainly have been submitted. The Lieutenant-Governor trusts, however, that now that Mr. Fuller is in charge, the next report will give a full and satisfactory account of the operations of the year.

4. The subjects treated of are—

(1) Experiments in the reclamation of *reh*-infected land on the Rawátpur Court of Wards' estate ;

(2) The adaptation and construction of improved agricultural implements for Indian use, which were conducted under Mr. Fuller's immediate direction ; and

(3) Experiments with water-lifts conducted mostly by Mr. Wilson.

5. Mr. Buck has prefaced the report with a review in which he describes the history and progress of the mechanical experiments going on with ploughs, water-lifts, and grain-cleaners. A really improved

plough would no doubt be an immense boon to the agricultural community, and it would seem has been all but secured. The native plough scratches and moves, but does not invert the soil. The object is to get a plough which will invert the soil in the English way, and at the same time be sufficiently light of draught for an ordinary pair of bullocks to draw, and sufficiently cheap to be within the means of an ordinary cultivator. An adaptation from an American plough is the one that has been adopted. Its weight is only 30lbs.; its average draught, turning a furrow 5″ × 3½″, is 120lbs.; and its price with wrought-iron work Rs 6, and with cast-iron work Rs. 5. Four hundred and thirty-nine have been sold during the year, and negotiations are in progress for the supply of the iron-work from America, when an article of better workmanship can be turned out than it is possible to produce in India, and at a price little in excess of Rs. 8, the limit within which it is considered the cost must be kept. But the accounts received of the new ploughs are not satisfactory from all districts, the difficulty being said to be their heavy draught. This is believed to be due to improper handling, and it has been determined in future not to send them out without a competent instructor to teach their use, and youths are being trained on the farm to meet this want. There is much truth, however, in what Mr. Fuller says in para. 14, that it is hopeless to expect the classes, who will not profit by the example of good agriculture already set them by several castes, to appreciate an improved plough, and it has yet to be seen whether one can be made up which will supplant the time-honored instrument in use to any large extent.

6. The experiments with water-lifts are fully detailed in an appendix by Mr. Wilson, and possess much scientific interest, besides showing the way in which problems connected with Indian agriculture have to be grappled with. The results, so far, are summed up by Mr. Buck in his review. Final conclusions have not yet been arrived at; but it is believed a chain-pump can be successfully used where water is not more than 20 feet from the surface.

7. The experiments in *reh* reclamation were carried on in 6 half-acre plots, and the processes which, it is hoped, may be successful to some extent, are:—

(1) Deep cultivation two months before the rains, and again at the commencement of the rains;

(2) Manuring with *madár* ashes; and

(3) Surface drainage.

It is too early as yet to form any definite conclusion; and, if they are to be of any real value, the cost of the experiments should be compared with the results.

I have the honor to be,

SIR,

Your most obedient servant,

C. ROBERTSON,

Secretary to Government,

N.-W. Provinces and Oudh.